

## TECHNICAL EXHIBIT FOR EXPERIMENTAL LICENSE APPLICATION

File #: 0012-EX-PL-2014

Submitted: February 5, 2014

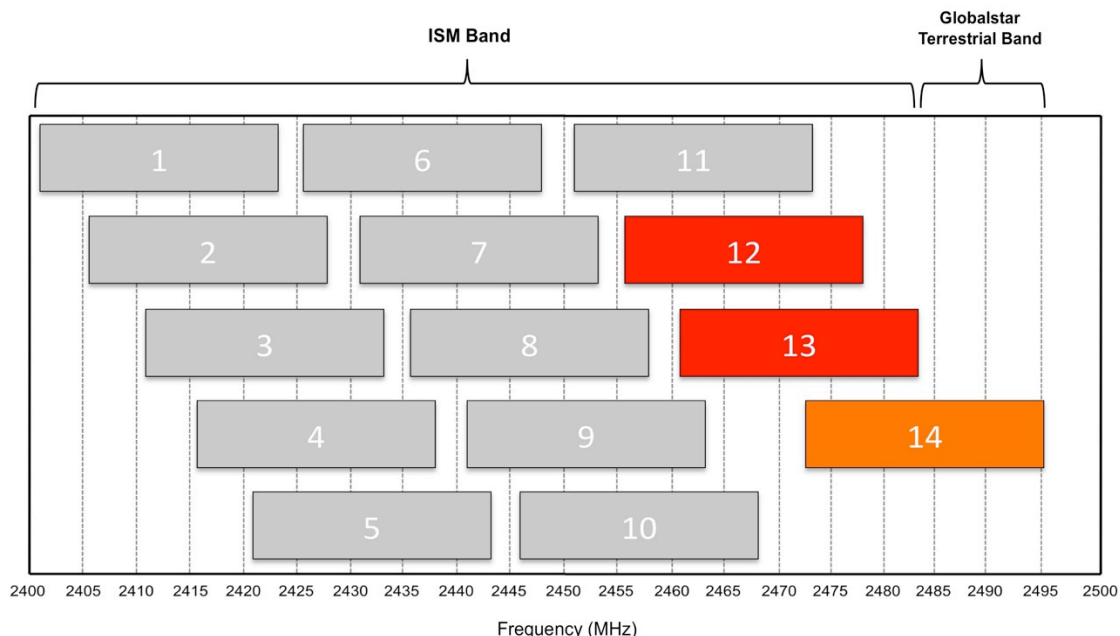
### Overview

In a recent petition for rule making (currently the subject of a Notice for Proposed Rulemaking: RM-11685), Globalstar outlined a unique new terrestrial application for Mobile Satellite Service (MSS) spectrum. The proposed Terrestrial Low Power Service (TLPS) would use 11.5 MHz of Globalstar S-Band spectrum paired with approximately 10 MHz of upper ISM spectrum to effectively enable the previously unusable 802.11 Channel 14 as a managed wireless service offering. This proposal is significant, since TLPS would mean a fourth orthogonal 802.11 channel in the extremely overcrowded and interference limited 2.4 GHz band. Most importantly, it is anticipated that licensed control of TLPS will permit the service to achieve and maintain extremely high spectral efficiencies.

The proposed research and experimental efforts will seek to determine the device performance requirements of carrier grade TLPS service, the implementation and network management techniques that achieve high spectral efficiencies, and the types of passive filtration and active modulation techniques that permit TLPS devices to comply with anticipated regulatory standards.

### Description of Proposed TLPS Service

The IEEE 802.11 standard specifies fourteen (14) 22 MHz channels in the 2.4 GHz band. These channels occupy spectrum in the range of approximately 2401 – 2495 MHz. Channels 1 through 13 have a 5 MHz center frequency of channel separation, with Channel 14 having a 12 MHz center frequency of channel separation. This channel configuration results in four (4) effectively non-overlapping 2.4 GHz 802.11 channels (see Figure 1).



**Figure 1:** 802.11 Channelization – The IEEE 802.11 standard specifies 14 channels in the 2.4 GHz band. These channels have a 5 MHz separation (except for Channel 14, which has a 12 MHz separation). In the United States, only channels 1-11 are authorized for unrestricted Part 15 operation. The spectral masks of Channels 12-14 extend outside the ISM band and into Mobile Satellite Service (MSS) spectrum above 2483.5 MHz.

While 802.11 was conceived by the IEEE to take advantage of Part 15 unlicensed operation in the 2.4 GHz Industrial, Scientific, and Medical (ISM) Band, both the frequency span and Out of Band Emissions (OOBE) limits imposed on the ISM Band precludes unlicensed operation of all 802.11 specified channels. The 2.4 GHz ISM allocation terminates at 2483.5 MHz, with emissions in the 2400 – 2483.5 MHz band being subject to attenuation equivalent to  $50 + 10 \log (P)$  dB of conducted output power at 2483.5 MHz (see Part 15.249(d)). This strict OOBE limit prohibits full power (30 dBm conducted output power, see Part 15.247(b)(3)) use of 802.11 Channels 12 (2456 – 2478 MHz) and 13 (2461 – 2483 MHz), while the band termination prohibits any use of Channel 14 (2473 – 2495 MHz) (see Part 15.205).

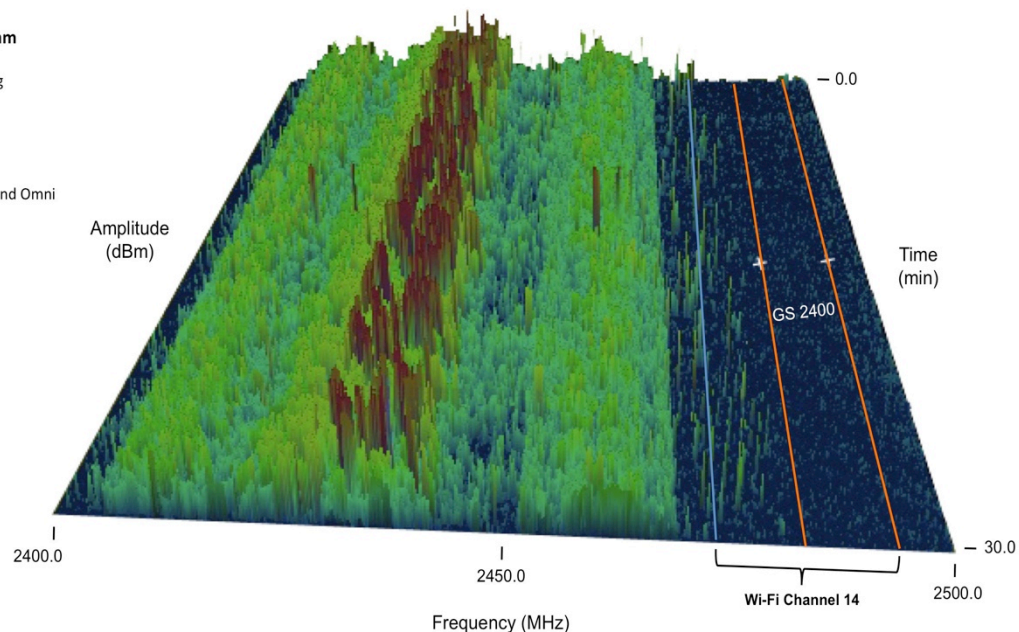
Strict OOBE limits associated with the ISM band termination are critical to the protection of Mobile Satellite Service (MSS) operations above 2483.5 MHz from uncoordinated terrestrial interference. However, the presence of these “edge of band” attenuation limits effectively create an 11 channel unlicensed 802.11 service in the United States, which terminates at 2473 MHz. This leaves more than 10 MHz of the upper 2.4 GHz ISM Band that is unusable by unlicensed broadband applications. In extensive spectral studies conducted throughout selected Metropolitan Statistical Areas (MSAs), only extremely low power and frequency agile Bluetooth emissions are commonly observed above 2473 MHz (see Figure 2).

#### Wideband 3D Spectrogram

42.36022 deg -71.06438 deg  
(Boston, MA)

START: 2.40 GHz  
STOP: 2.50 GHz

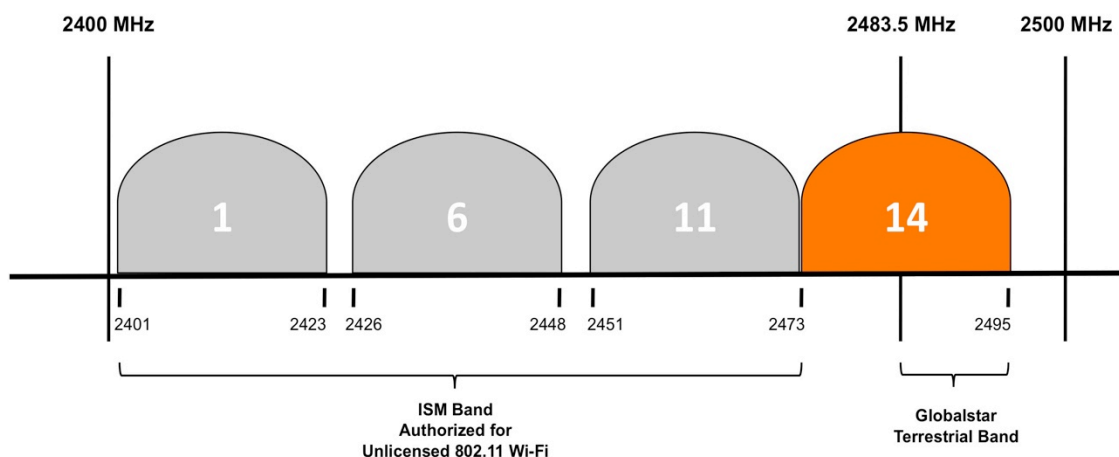
Anritsu MS2721A / Broadband Omni



**Figure 2:** 3D Spectrographic View of 2.4 GHz Band – An 802.11 enabled TLPS will straddle the Big LEO MSS terrestrial band (2483.5 – 2495 MHz) and a generally unused portion of the upper ISM band (2473 – 2483.5 MHz).

In most environments, MSS terrestrial spectrum exhibits extremely low interference levels, while the upper ISM band contains only transient low power Bluetooth emissions.

A Terrestrial Low Power Service (TLPS) contemplates use of IEEE 802.11 Channel 14 as a controlled broadband service that will operate at standard ISM power limits as defined in Part 15 (30 dBm maximum conducted output power / 36 dBm maximum Effective Radiated Power (ERP)). This service will occupy 11.5 MHz of terrestrially authorized MSS spectrum and approximately 10.5 MHz of upper ISM spectrum.



**Figure 3:** Channel 14 as Fourth Non-Overlapping Channel – Channel overlap in the IEEE 802.11 specification means that the overwhelming majority of 802.11 access points operate on Channels 1, 6, and 11. Thus, due to the extreme prevalence of unlicensed 802.11 activity, these three channels are highly compromised by the effects of co-channel interference. TLPS will liberate a fourth non-overlapping 802.11 channel, which will maintain low-interference and high spectral efficiency characteristics as a managed service offering.

Employing Channel 14 in the IEEE 802.11 specification to enable TLPS will create a number of unique advantages. These include:

- (a) Broad and Immediate Ecosystem – 802.11 compliant hardware is already capable of utilizing Channel 14 with a device firmware modification. This means that TLPS will benefit from a substantial existing ecosystem, which can be utilized almost immediately.
- (b) Use of Fallow Upper ISM Spectrum – TLPS permits a largely unusable portion of the ISM spectrum to be rapidly utilized in a manner that will protect critical MSS functionality through management of terrestrial interference.
- (c) High Broadband Capacity – A majority of mobile device data connectivity already occurs on the three interference prone non-overlapping public 802.11 channels (1, 6, and 11). A managed fourth non-overlapping channel will expand upon the already high spectral efficiency of ISM based 802.11 connectivity, adding significant additional broadband capacity.

## **Research and Experiment Equipment**

The proposed research and experiment program will use existing 802.11 compliant devices, such as tablets, smart phones, and other devices with 2.4 GHz 802.11 transceiver chipsets. The program will also use existing 802.11 compliant access points. In all cases, firmware modifications to the transceiver will enable operation of 802.11 Channel 14. Also, in all cases, conducted power output will not exceed 30 dBm and ERP will not exceed 36 dBm.

## **General Research and Experiment Objectives**

(a) Determine the precise noise and interference characteristics present in the 2473-2495 MHz band - Passive RF surveys of Channel 14 (2473-2495 MHz) will be conducted in the test environment for the purposes of understanding baseline noise and interference characteristics in this portion of S-Band spectrum.

(b) Determine the efficacy of the TLPS application - 802.11 Channel 14 will be enabled in commercial-off-the-shelf (COTS) devices and access points and a series of SNR and effective bit throughput tests on Channel 14 and other orthogonal 802.11 channels will be conducted in the test environment. The relative range, speed, and service quality of Channel 14 vs. public ISM 802.11 channels will be evaluated.

(c) Determine basic methods for control of TLPS operation - A rudimentary network operating system (NOS), which is equivalent to that employed in CMRS femto-cellular applications, will be enabled. This NOS will control TLPS co-channel interference through coordination of conducted output power levels and antenna radiation patterns.

(d) Determine the potential for TLPS regulatory compliance with existing devices - 802.11 Channel 14 will be enabled in existing low power devices (e.g. tablets and smart phones). The spectral regrowth characteristics of Channel 14 will be studied and power control / pulse shaping techniques applied to determine the maximum conducted output power where practical devices are in compliance with anticipated out of band emissions (OOBE) rules.



## Research and Experiment Objectives Specific to this License Application

### (a) Determine the efficacy of TLPS relative to public 802.11 channels in a rural transit environment.

While 802.11 networks are typically associated with indoor consumer and enterprise applications, outdoor 2.4 GHz Wi-Fi networks are an increasingly important element in carrier service strategies. However, despite the promise of outdoor Wi-Fi network coverage, the extremely high interference levels within the 2.4 GHz ISM Band frustrate the practical realization of wide area coverage models. This is especially true for strand mounted APs that are configured to service subscribers in transit on a roadway.

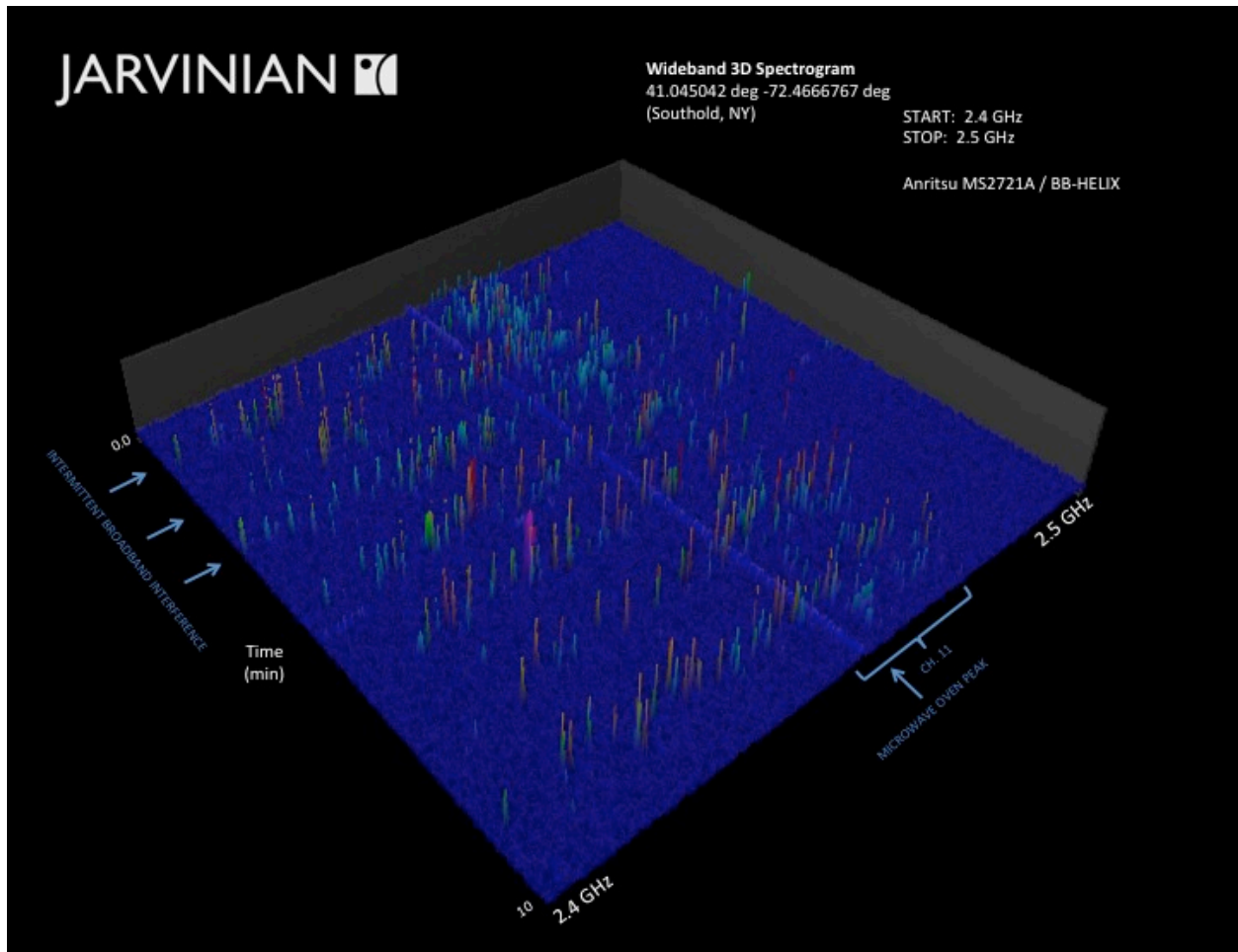
Figure 4 illustrates a rural transit application of public channel APs on Long Island, New York. In this system, access points (APs) are placed approximately 1000 meters apart along Route 48. Directional antennas are used to direct signal in a manner that follows the approximate contours of the roadway (see Figure 6).

As would be inferred from the rural surroundings, public channel 802.11 interference is minimal in this environment. However, at strand height, intermittent high power interference may be observed from a broadband ISM data system (see Figure 5). This system likely compromises marginal Wi-Fi connections, even where local interference on channels 1-11 is minimal. TLPS is largely immune to such interference and may permit more consistent speed / QoS in such environments.

The proposed test will employ both 802.11g/n OFDM and the more primitive but Doppler tolerant 802.11b DSSS. It is our belief that 802.11b may be more effective for transit applications where average vehicle speed is in excess of 20 kilometers per hour.



**Figure 4:** Strand Mounted Wi-Fi Links for Rural Transit – Roadway Wi-Fi access points offer significant broadband offload potential. However, the interference-limited nature of the 2.4 GHz ISM band makes public 802.11 channel implementation difficult. Three of the proposed test locations are located approximately 1000 meters from one another on a rural portion of Route 48 in Southold, New York.



**Figure 5:** ISM Interference in Rural Environments – The test coordinates described in Figure 4 are in an extremely low-density rural environment with a minimum of public channel 802.11 activity. However, despite this, significant interference threats still exist for APs at strand height. As seen in the figure above, strong intermittent interference from a high power emitter causes significant disruption to the 2.4 GHz ISM band.



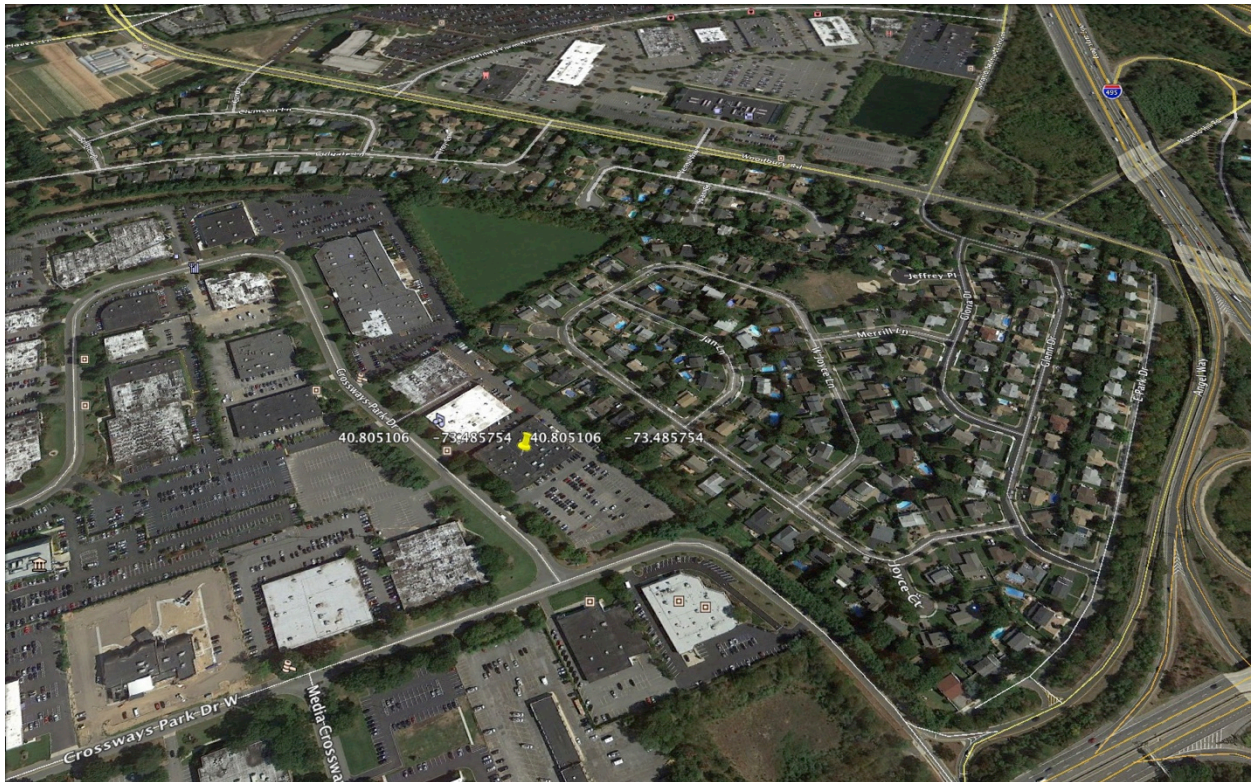


**Figure 6:** Configuration of Rural Transit Strand Mount APs – 802.11 access points at strand height may be used to service subscribers while in transit. The site pictured above (41.045042 deg, -72.4666767 deg) has transceivers with directional antennas designed to follow the contour of the roadway.

**(b) Determine the efficacy of TLPS relative to public 802.11 channels in a low-density enterprise environment.**

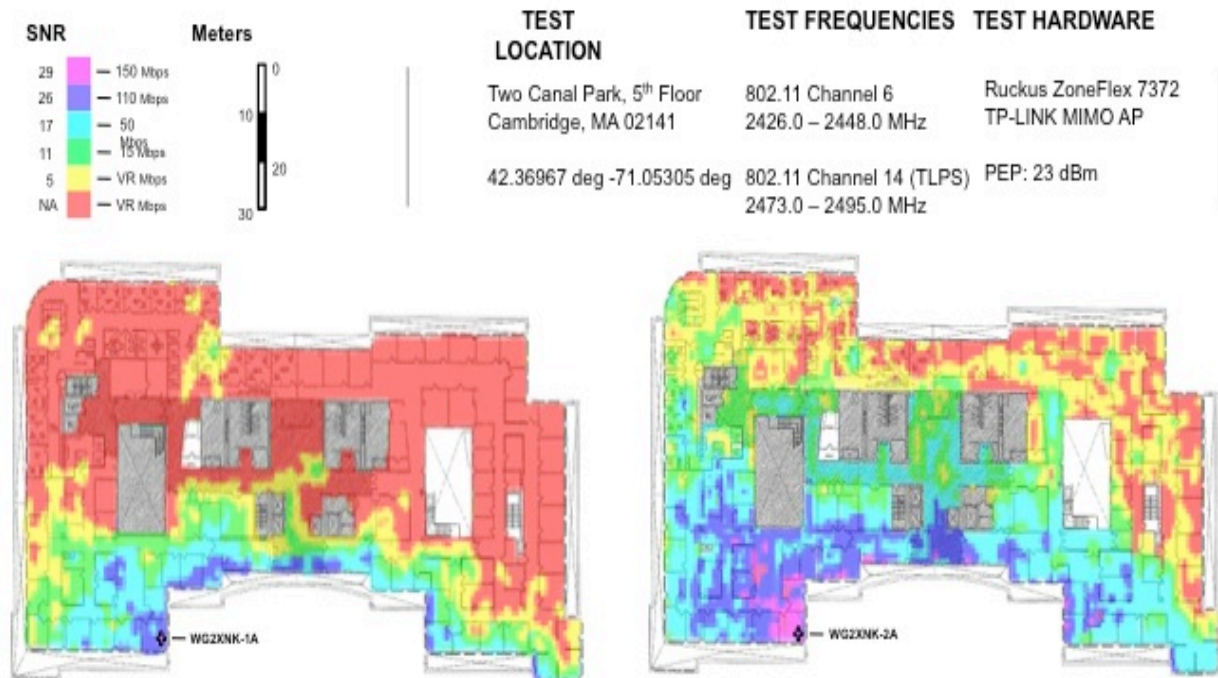
The enterprise environment represents one of the most critical and challenging applications of 802.11 technology. As the wired broadband pipe has become ever wider, 802.11 connectivity within office environments is the essential limiting factor for data speeds experienced by users. Even where fiber based connectivity is in the Gigabit range, users may still only experience low Megabit data speeds if their primary interface is over an interference limited 802.11 link.

Figure 7 describes an enterprise test location on Long Island, New York. This location represents a low-density office environment. Here, we expect a minimum of local environmental interference, with ISM traffic throughout the building representing the bulk of public channel challenges. This testing will build upon that summarized in Figure 8 for Cambridge, Massachusetts (experimental license: WG2XNK). We predict a similar relationship between signal-to-noise-ratio (SNR) for public channels and TLPS spectrum in this environment.



**Figure 7:** Low Density Enterprise Environment – A representative low-density office environment in a suburban part of Long Island, New York. Interference from the nearby residential area and commercial park contribute to a typically crowded 2.4 GHz ISM Band.



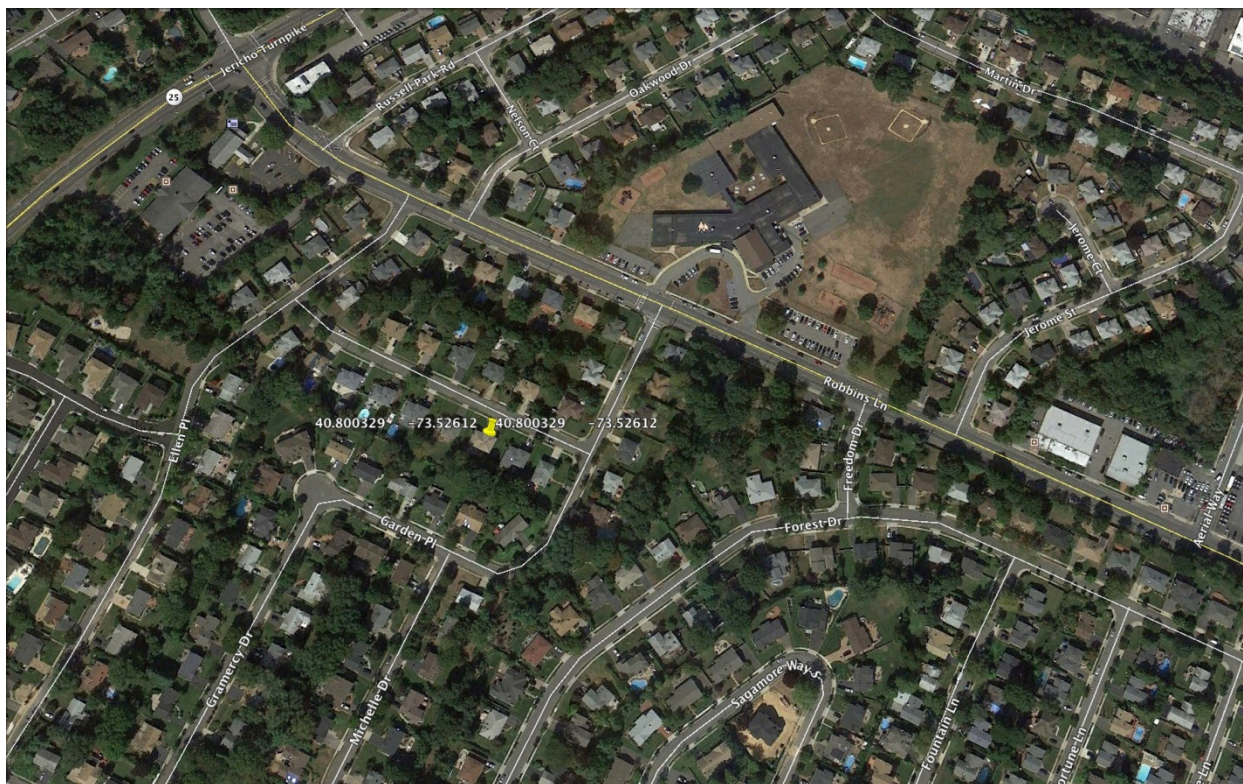


**Figure 8:** SNR Comparison in Enterprise Environment – Even in semi-urban settings, the significantly lower noise floor and interference levels associated with TLPS spectrum yield much higher sustained SNRs relative to 802.11 operations on public 2.4 GHz ISM channels. Higher SNRs mean significantly higher data throughput speeds in environments that are compromised by uncoordinated Wi-Fi and other unlicensed utilization.

**(c) Determine the efficacy of TLPS relative to public 802.11 channels in a moderate-density suburban single-family home environment.**

Consumer applications place extreme pressure on the 2.4 GHz ISM band. In particular, Wi-Fi activity on the three public non-overlapping channels (1, 6, and 11) represents the bulk of data connectivity in the home. Despite the large amount of public spectrum available in the 5 GHz band, we believe that the propagation advantages associated with 2.4 GHz will make this band the primary home connectivity mechanism throughout the foreseeable future. 2.4 GHz readily penetrates common building materials, permitting a single access point to service a typically sized residential dwelling.

Unfortunately, despite the propagation advantages of 2.4 GHz, the interference issues associated with the ISM portion of the band are rapidly eroding its utility. Even in low-density environments, powerful microwave oven emissions (centered at 2.45 GHz) and the growing population of consumer devices with 802.11 access is creating unacceptable SNIRs (Signal to Noise plus Interference Ratios) in the home. This threatens a broad diversity of applications, particularly those that are bit intensive and latency intolerant (e.g. live video, gaming, etc.).



**Figure 9:** Single Family Home Application – Consumer home applications are amongst the most demanding upon 802.11 in the 2.4 GHz band. The proposed test location will evaluate TLPS performance in a moderate-density suburban environment.

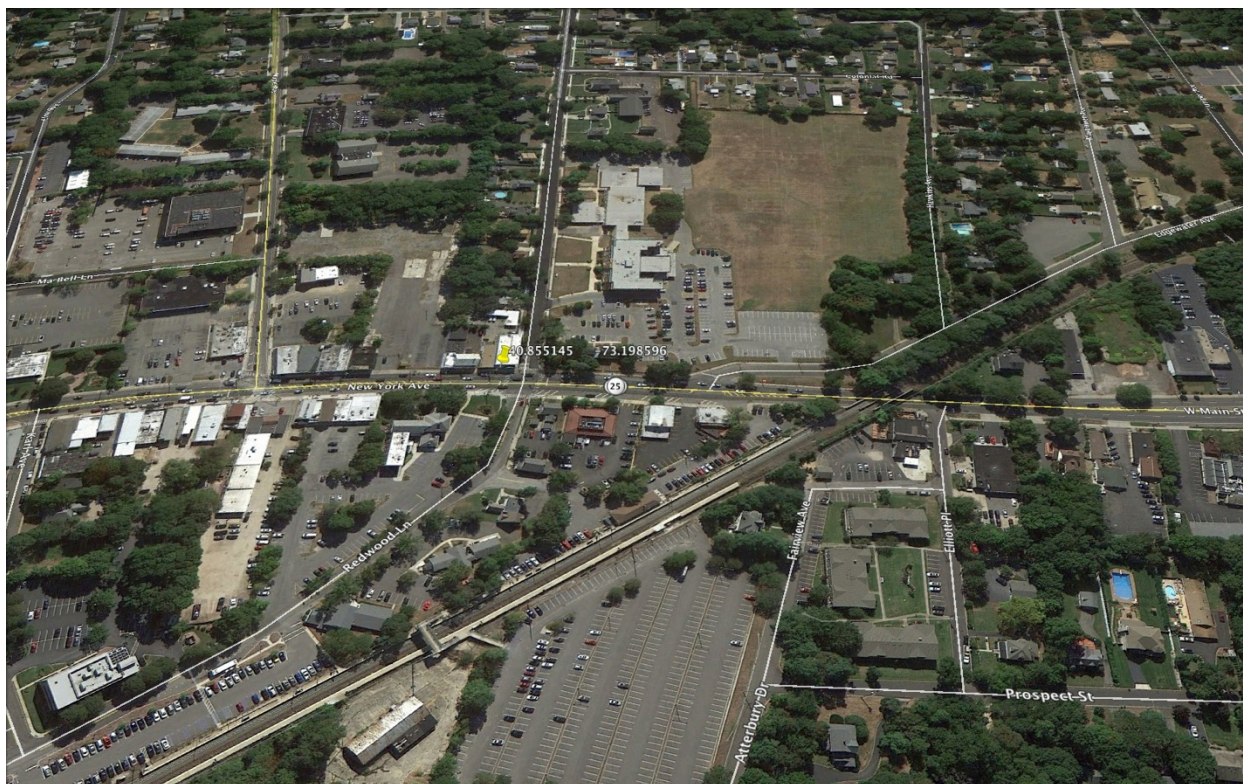
**(d) Determine the efficacy of TLPS relative to public 802.11 channels in moderate-density outdoor suburban environment.**

The suburban “main street” environment is one of the most common examples of outdoor carrier access point deployment. Containing both sedentary and mobile data users, this environment theoretically offers many opportunities for efficient data offloading from macro wireless networks. However, despite the perceived utility of public APs in such applications, the “main street” environment is often highly interference limited on ISM frequencies. The result is a frustrating experience for carrier Wi-Fi users.

Figures 10 and 11 illustrate a proposed test area in suburban Smithtown, New York. In this environment, a strand mount access point with low gain antennas is designed to service what appears to be a relatively light traffic area. Yet, the outward appearance is misleading. Detailed spectral analysis in Figures 12 and 13 show the RF picture of the same environment. Even at street level, the public 802.11 spectrum is saturated by interference.

The proposed testing will seek to evaluate the performance benefit (speed / range) associated with TLPS in this highly representative outdoor deployment.



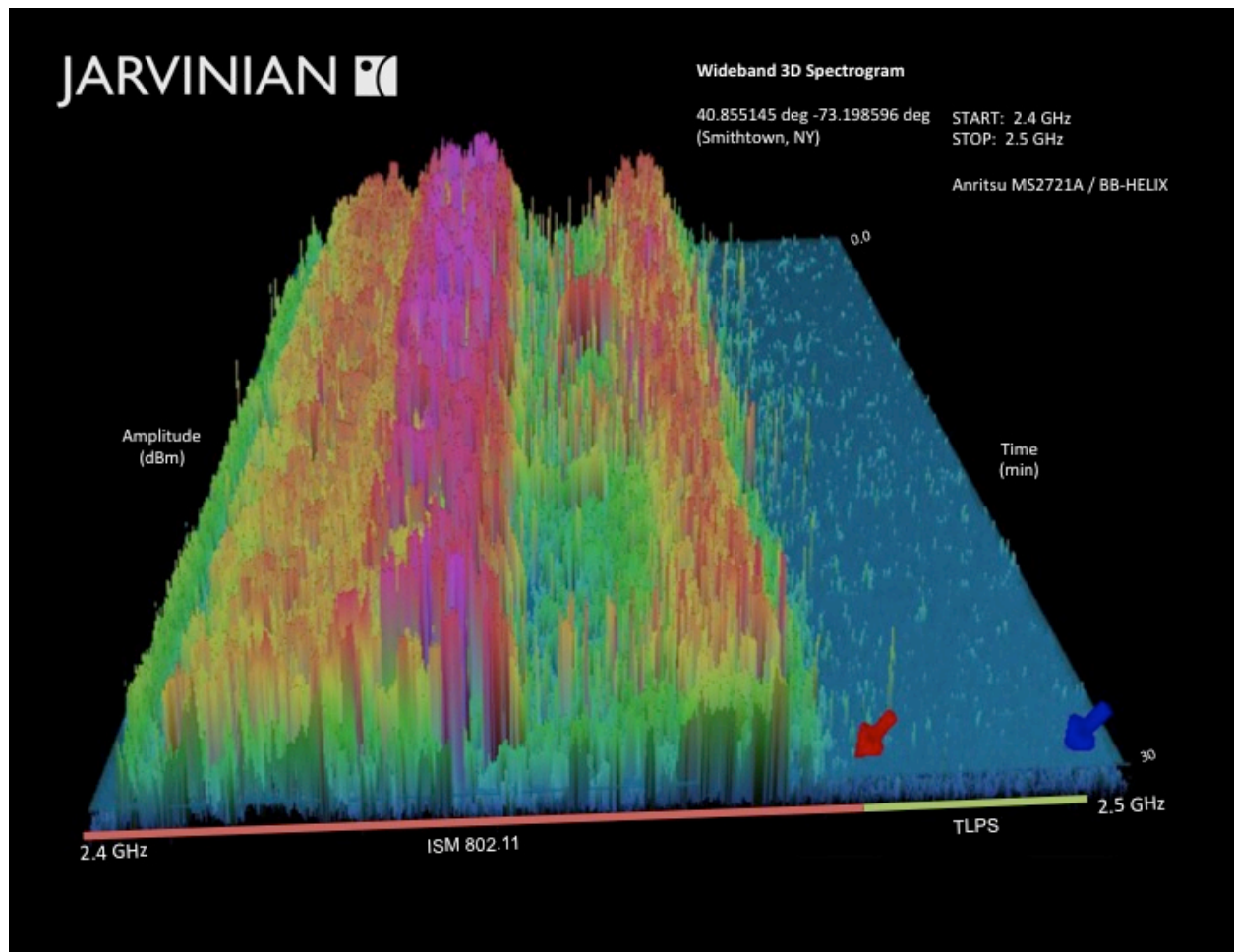


**Figure 10:** Outdoor Moderate-Density Suburban Environment – The suburban “main street” environment is a compelling location for carriers to offload data traffic that would otherwise congest macro cellular infrastructure. However, even a moderate-density environment may contain a significant amount of 2.4 GHz ISM interference.

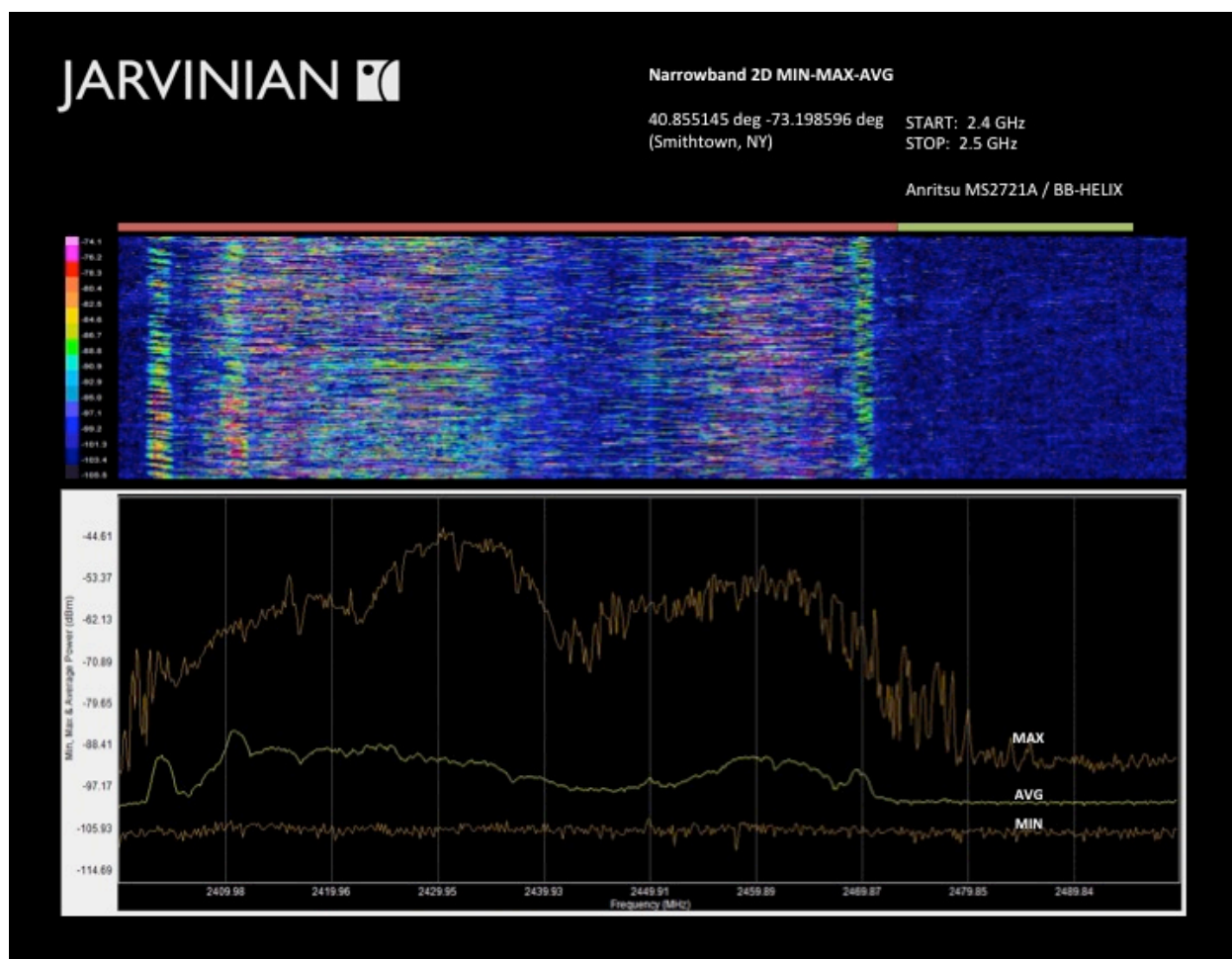




**Figure 11:** Strand Mount AP in Moderate-Density Outdoor Environment – The proposed location of this test are in a minimally occupied area of Smithtown, NY. However, despite the relatively low level of foot traffic, local 2.4 GHz ISM Band interference is severe.



**Figure 12:** Severe 2.4 GHz ISM Interference – Despite the relatively minimal amount of perceived activity in nearby shops / establishments, ISM interference at street level is very significant for the proposed Smithtown, New York test location. Meaningful public 802.11 data link activity is observed alongside a measureable background of broadband microwave oven noise. We may assume that the level of interference experienced by an AP at strand height is yet more severe.



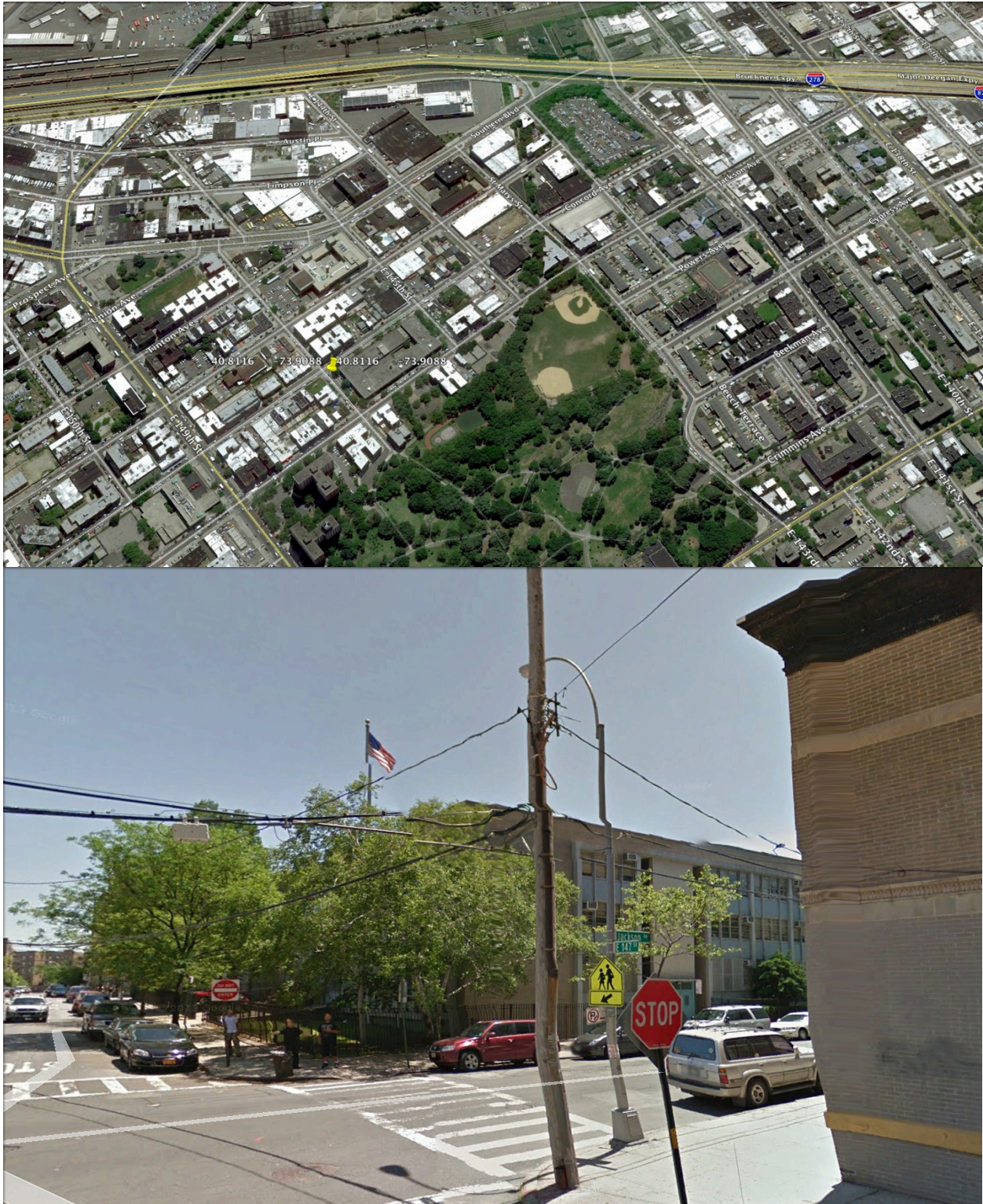
**Figure 13:** Severe 2.4 GHz ISM Interference – A 2D Min / Max / Average version of Figure 12, the distribution of energy across the public 802.11 band may be seen more clearly. An ordinary laptop may detect 50-75 discreet public channel APs in this environment.

**(e) Determine the efficacy of TLPS relative to public 802.11 channels in moderate-density urban environment.**

Urban environments are characterized by extremely high noise / interference in the 2.4 GHz ISM band, and New York City is often cited as a particularly severe case study for such conditions. However, portions of the South Bronx represent an unusual subset of the urban environment. Subject to the same generalized interference contributors (e.g. microwave ovens, non-compliant WISPs, etc.) as other portions of the metropolitan area, this comparatively low-density environment displays lower average 802.11 channel activity than other portions of New York.

The proposed test will evaluate the impact of more generalized 2.4 GHz noise and interference contributors on public channel throughput and the relative benefit of TLPS throughout the same environment. Secondly, the test will evaluate the ability of strand mount access points to provide service for educational purposes within a school zone.





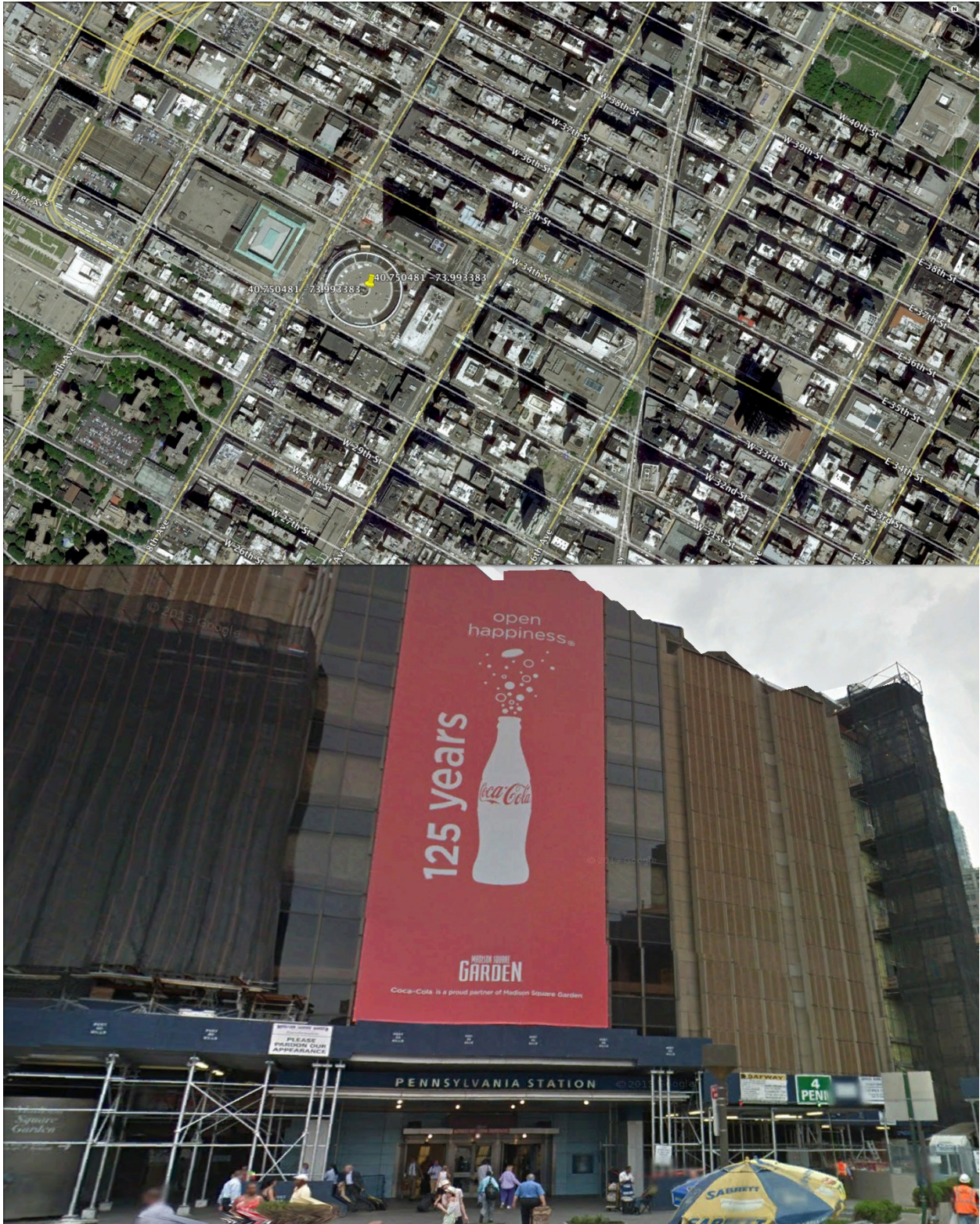
**Figure 14:** Moderate Density Urban Environment – The proposed test location shown above is in the South Bronx portion of New York City. While localized 802.11 activity is not as dense as other portions of the metropolitan area, this region suffers from both a generally high 2.4 GHz noise floor and the effects of high ERP emission for WISPs and backhaul applications.

**(f) Determine the efficacy of TLPS relative to public 802.11 channels in a high-density urban environment.**

Midtown Manhattan represents one of the most extreme environments for 2.4 GHz in the United States. As a result, public access point utility has become extremely limited in this portion of the New York metro area. This is unfortunate as Manhattan represents a service area where the need for macro network offload is most acute.

The proposed test will evaluate the relative capacity of TLPS over that of public 802.11 channels in the extremely high density indoor environment of Madison Square Garden / Pennsylvania Station.





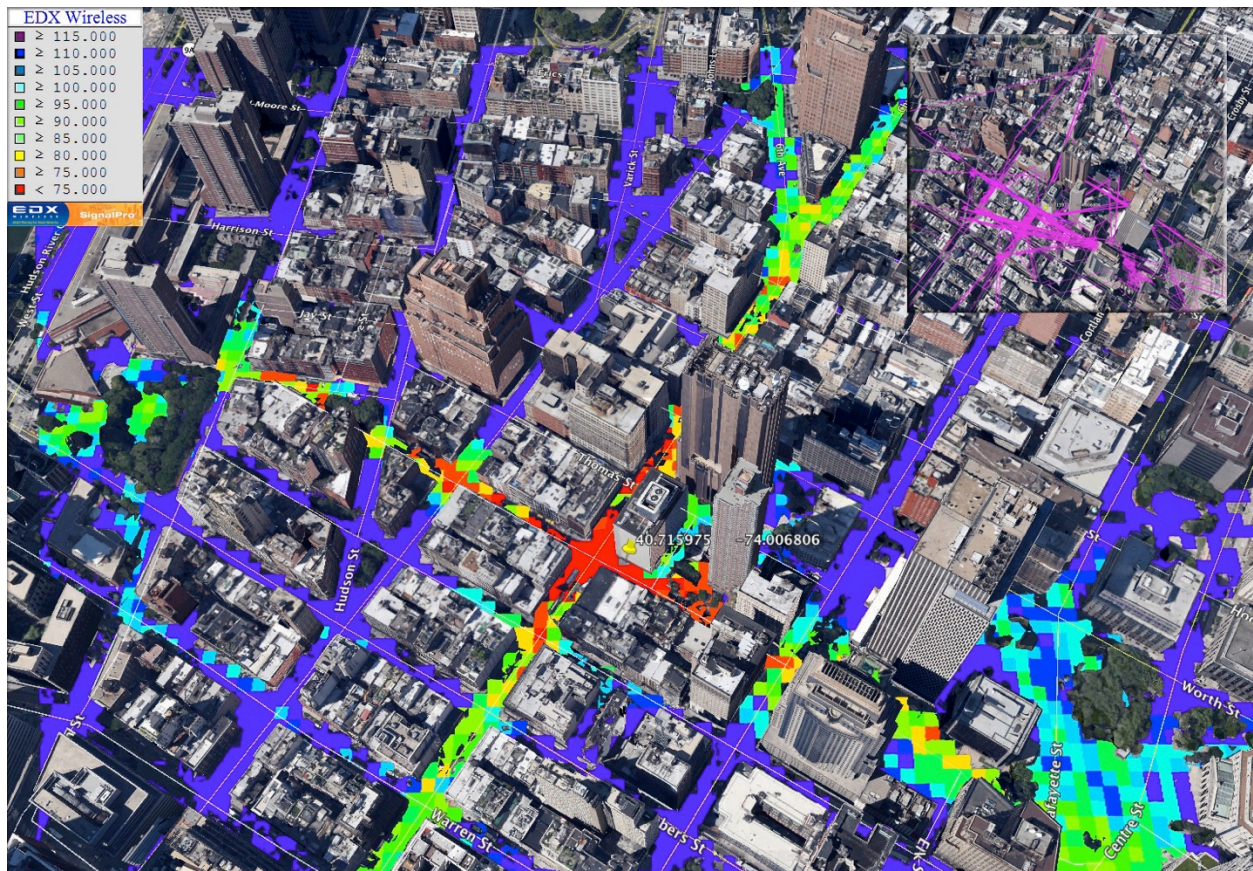
**Figure 15:** High Density Urban Environment – Manhattan represents one of the most hostile RF environments in the United States. At 2.4 GHz ISM frequencies, overwhelming interference severely constrains outdoor and large indoor venue use of public 802.11 channels. The proposed test will evaluate indoor TLPS performance in the heavy traffic Madison Square Garden / Pennsylvania Station area.



**(g) Determine the efficacy of TLPS for small cell applications in a high-density urban environment.**

By definition, urban wireless environments are spectrum constrained and must rely heavily upon intricate cellular reuse strategies to meet capacity needs. Figure 16 depicts a complex ray tracing propagation analysis for 2.4 GHz in lower Manhattan. As can be easily seen, the propagation physics of the band are very well suited to small cell deployment, even if the interference conditions are not.

The proposed testing will evaluate the potential for TLPS to be used effectively in a low power small cell context.



**Figure 16:** Small Cell Utilization of TLPS – A complex ray tracing-based analysis of 2.4 GHz propagation in lower Manhattan (source: EDX Wireless) illustrates the superior potential for a non-interference limited parcel of this spectrum to service high density small cell applications.